features and a second surface comprising a second plurality of surface features. The two surfaces are substantially parallel to one another and configured to move together. The haptic effect generator also comprises a follower to follow a surface, and an actuator to move the follower from the first surface to a second surface.

In one embodiment, the haptic effect generator may be configured to comprise a cylinder having a plurality of cams, and a lever operable to engage at least one of the plurality of cams. The plurality of cams may have the same or different mechanical configurations. The lever may comprise a spring-loaded lever, a spring-loaded pin, a pawl, and/or other suitable structure. As another example, the haptic effect generator may comprise a brake. A single-part shoe brake or other suitable brake may be used. A screw or other structure may be used to vary a friction exerted by the brake. A DC motor or other device may be used to turn or move the screw or other such structure.

As another example, the haptic effect generator may be configured such that it may be operable to alter a surface of the manipulandum. A pin or other structure may be positioned below the surface of the manipulandum. The haptic effect generator may comprise a slider operable to project the pin above the surface of the manipulandum.

One embodiment comprises device comprising a manipulandum, such as a button. The manipulandum comprises a surface, a portion of which defines a hole. The device also comprises a pin configured to move through the hole from a first position at or below the surface to a second position above the surface. An actuator in communication with the pin moves the pin from the first position to the second position.

Devices according to the present invention may also include other features. For example, a membrane or other structure may be placed proximate to the surface of the manipulandum such that it may prevent foreign matter from interfering with the operation of the haptic effect generator. As another example, a processor may be in communication with the actuator and be operable to affect a switch between the first of the at least two haptic profiles and the second of the at least two haptic profiles.

There are a variety of methods that may be carried out in accordance with the present invention. One method according to the present invention comprises generating an output signal operable to cause an actuator to switch a haptic effect generator from a first haptic effect to a second haptic effect. The haptic effect generator used in such a method may comprise a first mechanical configuration associated with the first haptic profile and a second mechanical configuration associated with the second haptic profile, or another configuration. A method according to the present invention may also comprise receiving an input signal associated with a haptic effect switch. The input signal may be associated with a device state or other data. In one embodiment of a method according to the present invention, the actuator comprises a DC motor. The output signal may comprise any suitable signal. For example, the output signal may comprise a positive pulse. The level of the pulse may be proportionally higher than a previous maximum. As another example, the output signal may comprise a negative pulse, proportional to the current level of friction, and a positive pulse of a magnitude proportional to the desired level of friction.

Embodiments of the present invention may also include a computer-readable medium encoded with code to carry out such methods. Any suitable code type may be used.

Below, systems and methods in accordance with the present invention are described with reference to FIGS. **1**-**8**.

The present invention is not limited to the examples given, but the examples are given to illustrate types of embodiments of the present invention.

## Examples with Reference to the Figures

Referring now to the drawings in which like numerals indicate like elements throughout the several figures, FIG. **1**A is a schematic diagram illustrating a knob with programmable detent profiles in one embodiment of the present invention. Embodiments of the present invention provide systems and methods for providing haptic feedback to a user that minimizes the consumption of power. Haptic feedback provides tactile sensations that depend on movement, such as movement of a user's hand or of an actuator. In one embodiment of the present invention, the power for providing the haptic effect is provided by a user moving a manipulandum. The user experiences multiple haptic profiles that depend on multiple stable mechanical configurations or a low-power device.

In one embodiment of the present invention, haptic sensations depend on an external agent such as a computer, or more generally, a circuit that is aware of information external to the device. Hence such embodiments may be programmable. In other embodiments, a user utilizes a mode selector, which controls the haptic profile, or a manufacturer performs a mode selection before installing the device.

The embodiment shown in FIG. **1**A comprises a knob **102**. A user can rotate the knob **102** to perform some function, such as selecting a song from a play list on a digital music player. The knob **102** is connected to a haptic effect generator comprising a cylinder **104**. A haptic effect generator is a device capable of generating a haptic effect, either directly or indirectly, on a manipulandum. The cylinder comprises four cams **104***a*-*d* having distinct mechanical (physical) profiles determining the haptic effect generated on the knob **102** and felt by the user manipulating the knob **102**.

Each one of the four cams **104***a*-*d* provides a different haptic profile. A haptic profile comprises a pre-defined set comprising one or more haptic sensations, such as bumps, detents, stops, or other sensations. For example, in one embodiment, the first cam **104***a* is smooth and provides haptic feedback similar to a potentiometer. The second cam **104***b* (FIG. **1**B) includes detents **103***b* that are shallow and closely spaced, providing haptic feedback similar to what is often provided by conventional audio volume controls. The third cam **104***c* includes a detent in the center of rotation and is otherwise smooth, providing haptic feedback similar to what is often provided by conventional tone, balance, or fader controls of an automotive audio system. The fourth cam **104***d* (FIG. **1**C) includes four deep detents **104***d* spread evenly between two hard stops **105***d*, providing feedback similar to what is often provided for a fan control of an automotive climate control system. Another example of a cam including protrusions **103***x* is shown in FIG. **1**D.

In the embodiment shown, a slider **106** on a square shaft **108** holds a lever comprising a leaf spring **110** terminated by a ball **112**. The ball **112** presses on one of the cams **104***a*-*d*. The pressure of the ball **112** on the cam **104***a*-*d* provides the haptic effect. When the ball **112** is in a cam **104***a*-*d*, the mechanism provides a stable mechanical configuration. The mechanical configuration does not change until the actuator acts upon the haptic effect generator. In another embodiment, a spring-loaded pin is used instead of the lever.

In the embodiment shown in FIG. **1**A, an actuator determines the position of the slider **106**. The actuator comprises a solenoid **114** with four coils **116***a*-*d* and one iron core **118**. The iron core **117** is connected to the slider **106** by a rod **120**.